APPENDIX F – LTE UE TRP Data

The graphs in Figure 42 and Figure 43 present the antenna pattern and radiating efficiency of the LTE UE used in this project. These graphs present the Azimuth 90° and Elevation 0° positions; however a full pattern was taken in order to calculate the Total Radiated Power (TRP) of the devices. Following these comparative graphs, individual graphs of each LTE UE are presented, showing the pattern variation at different transmission bandwidths.

The three phones tested here were the Bandrich C525, the Samsung R930, and the Samsung Galaxy Note.

Table 58 reports the TRP for the various LTE UE and transmission signals measured. While all LTE UE will produce close to 23 dBm at their internal connection point, in order to meet 3GPP requirements, none were found which did not exhibit losses between that point and the energy radiated from the device. For the two handsets measured these losses were very significant. While undoubtedly manufacturers will try to reduce these losses, it seems reasonable to conclude that the values measured represent what is reasonably achievable with current technology and other factors that influence this outcome.

Table 58 – TRP for LTE UE used

Total Radiated Power (TRP)			
Manufacturer	Bandrich	Samsung	Samsung
Model	C525	R930	Galaxy Note
Band Class	12	12	17
Transmitted Signal			
5 MHz 25 Resosurce Blocks	20.1 dBm	13.8 dBm	14.6 dBm
5 MHz 2 Resosurce Blocks	20.5 dBm	13.1 dBm	13.3 dBm
3 MHz 15 Resosurce Blocks	19.8 dBm	13.8 dBm	
3 MHz 2 Resosurce Blocks	20.5 dBm	14.0 dBm	

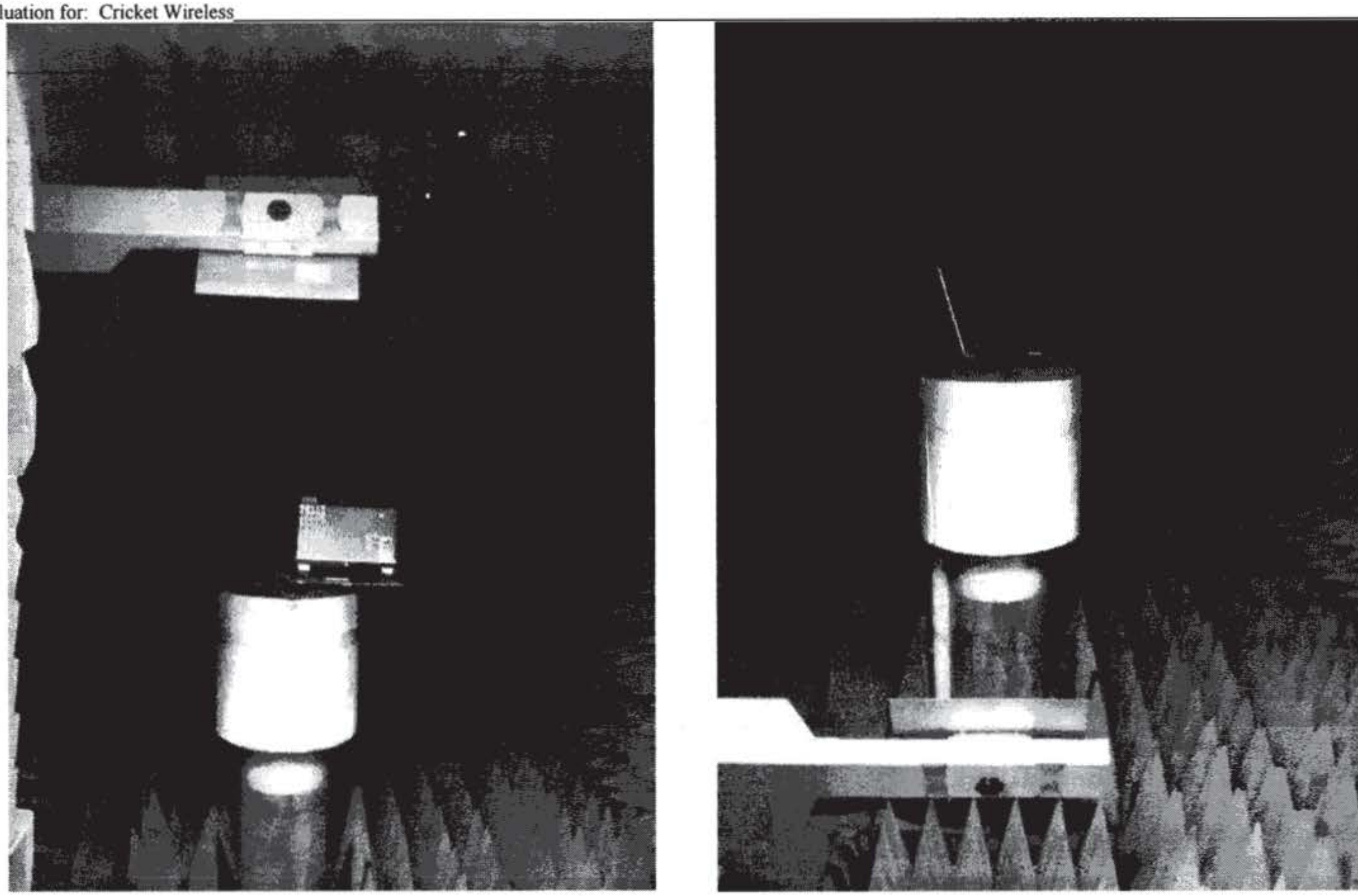


Figure 41 – Antenna pattern testing of BandRich C525 USB Dongle to measure total radiated power (TRP)

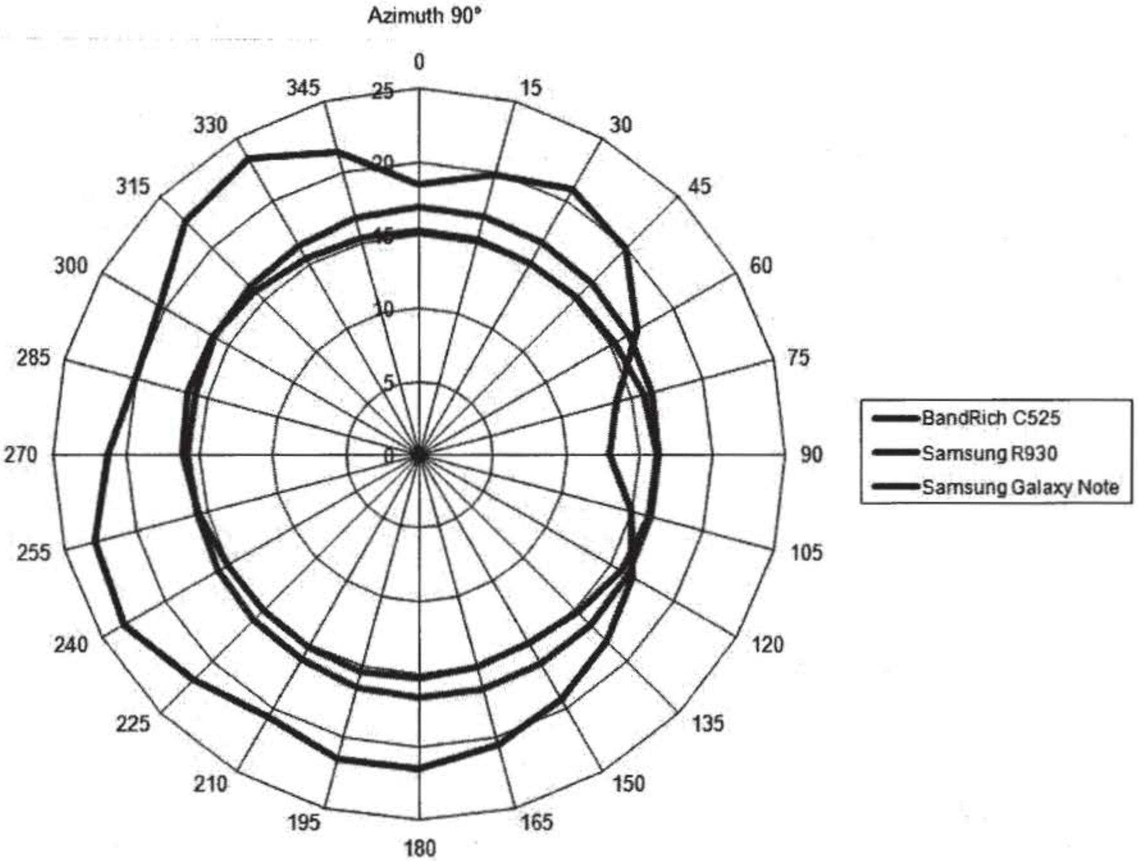


Figure 42 – Comparison of Three LTE UE devices at the Azimuth 90

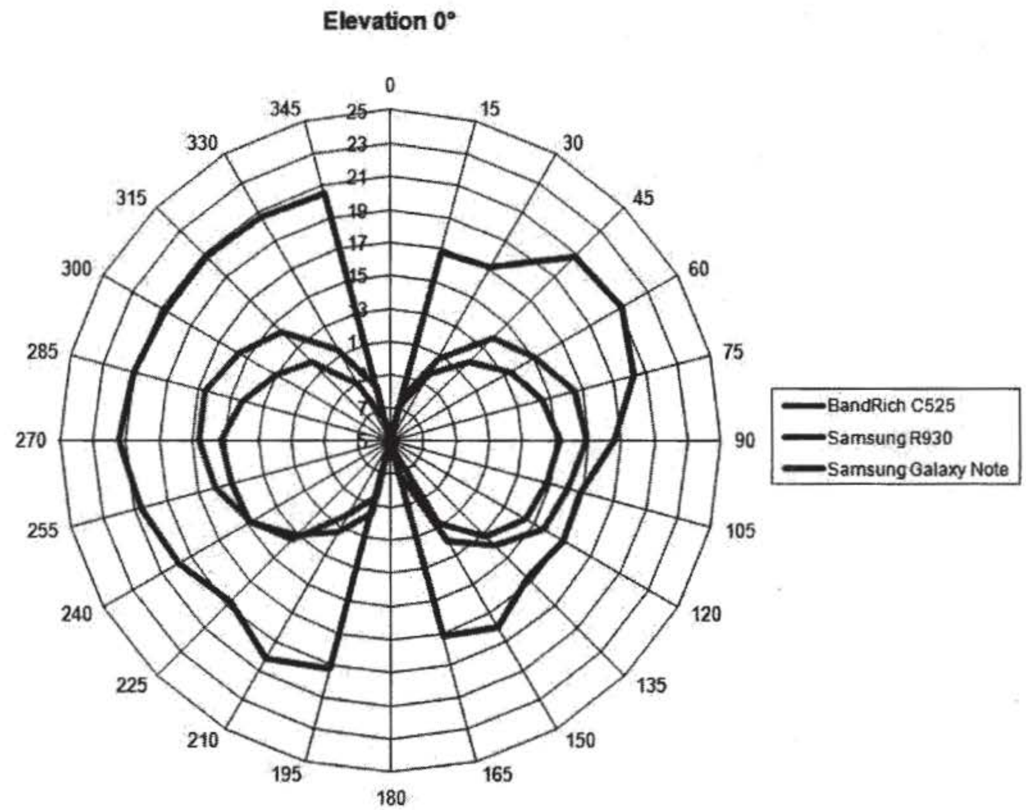


Figure 43 – Comparison of Three LTE UE devices at Elevation 0°

Figure 44 and Figure 45 display the BandRich USB dongle's TRP for four transmission bandwidths. Note that the values for some bandwidths are close enough so that they are not easily discernable.

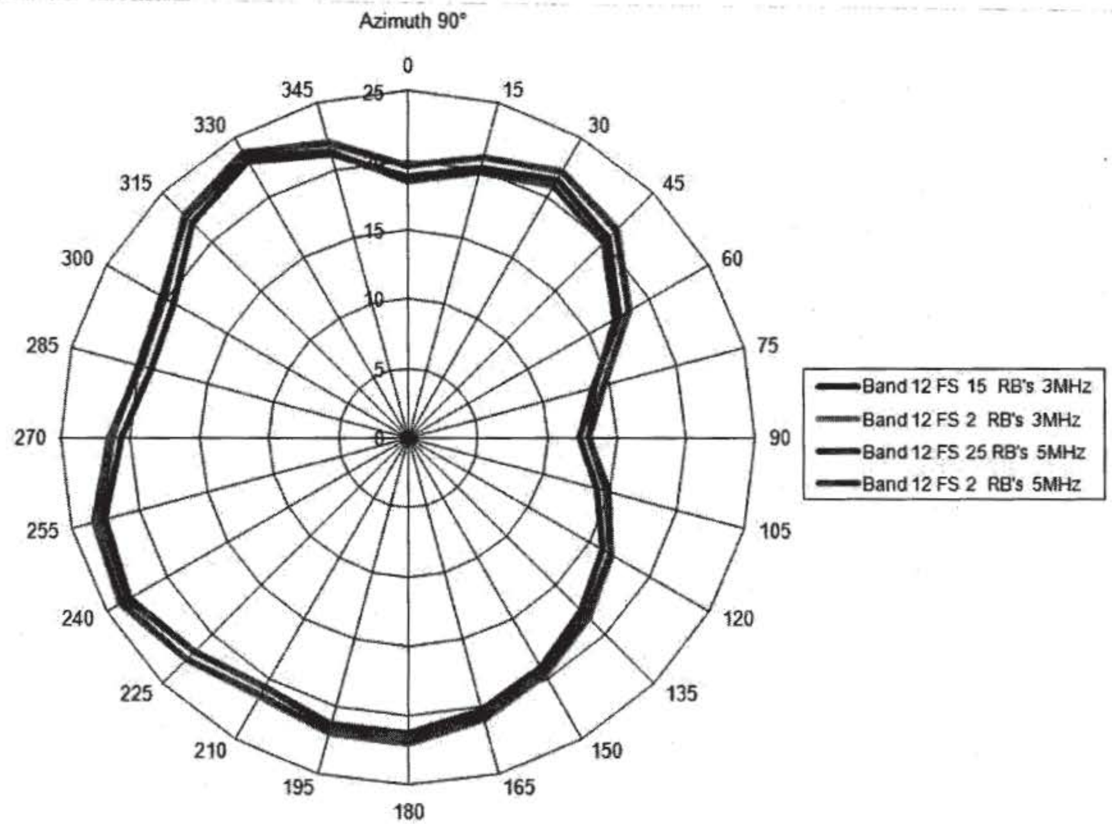


Figure 44 – Comparison of Four Bands of BandRich Phone at Azimuth 90°

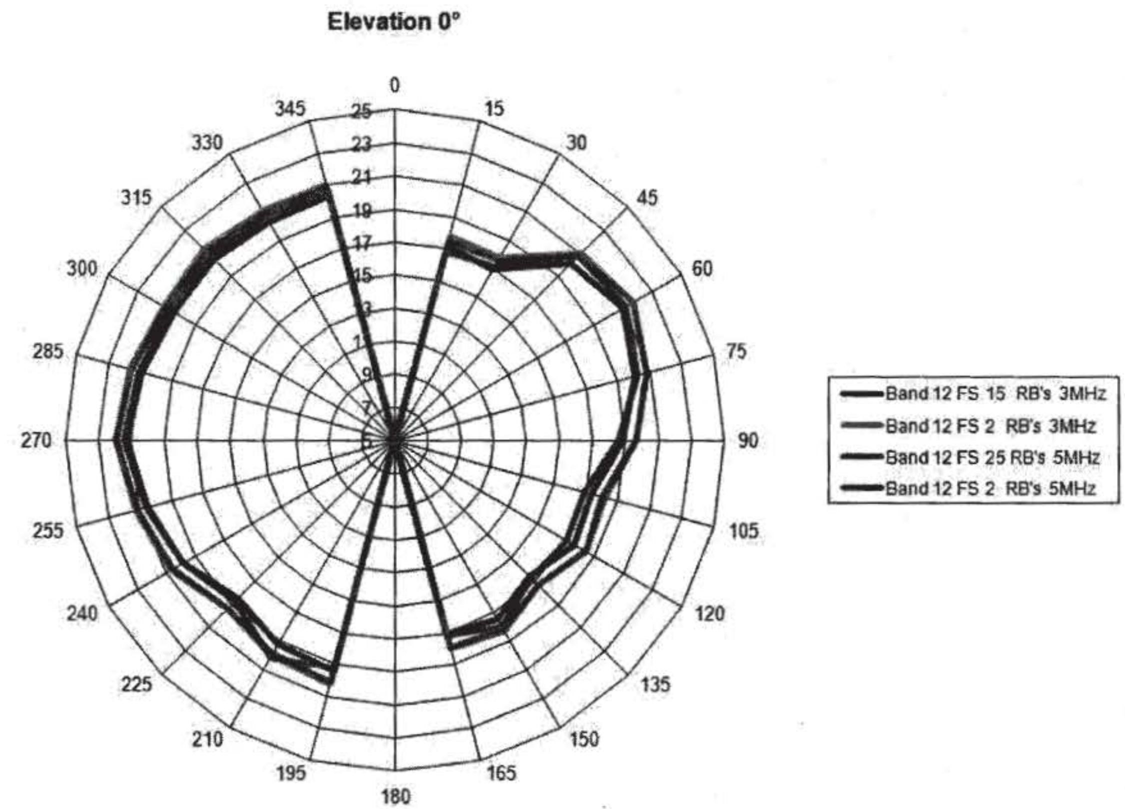


Figure 45 – Comparison of Four Bands of BandRich Phone at Elevation 0°

Figure 46 and Figure 47 compare the four bands of the Samsung R930 at Azimuth 90° and Elevation 0°.

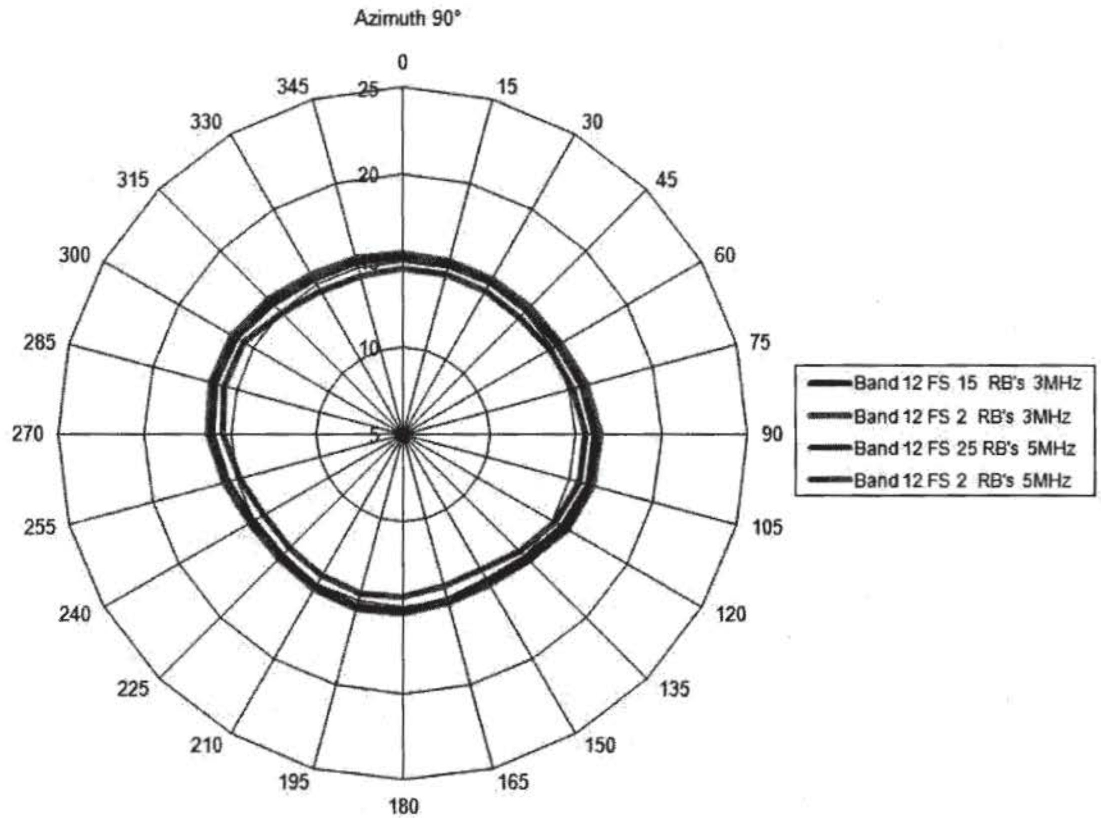


Figure 46 – Comparison of Four Bands of Samsung R930 at Azimuth 90°

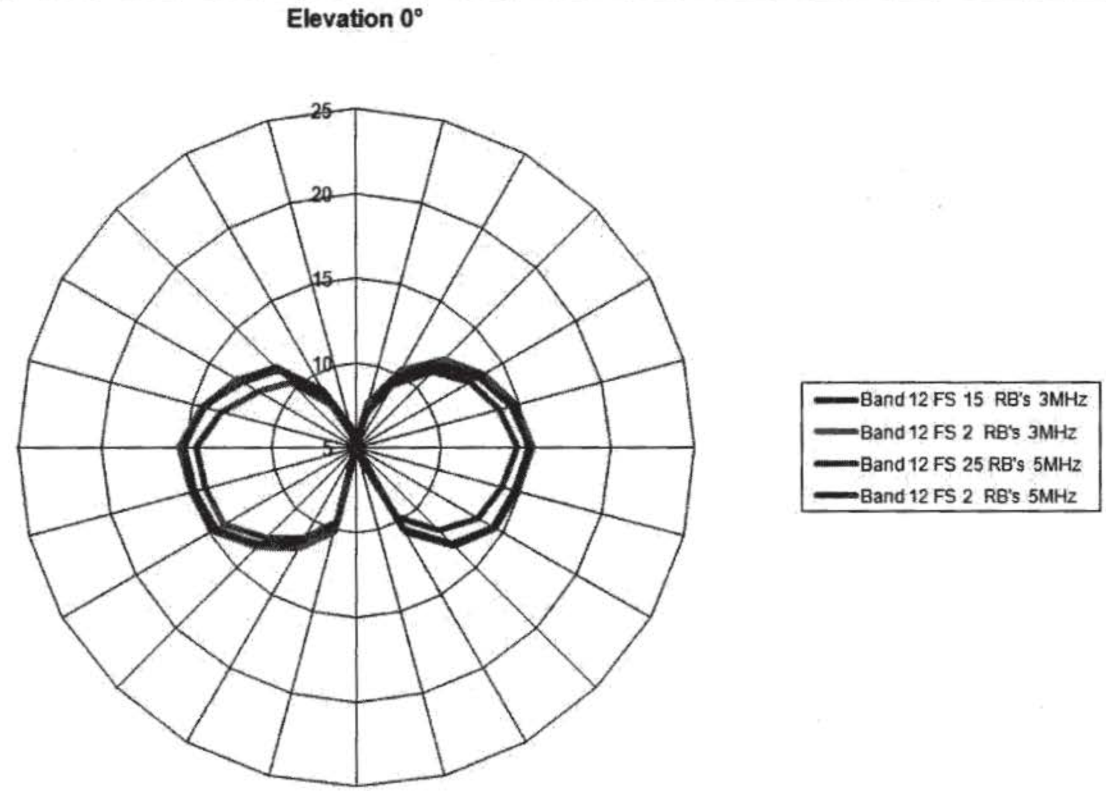


Figure 47 – Comparison of Four Bands of Samsung R930 at Elevation 0°

Lastly, Figure 48 and Figure 49 show the data from the Galaxy Note taken at Azimuth 90° and Elevation 0°

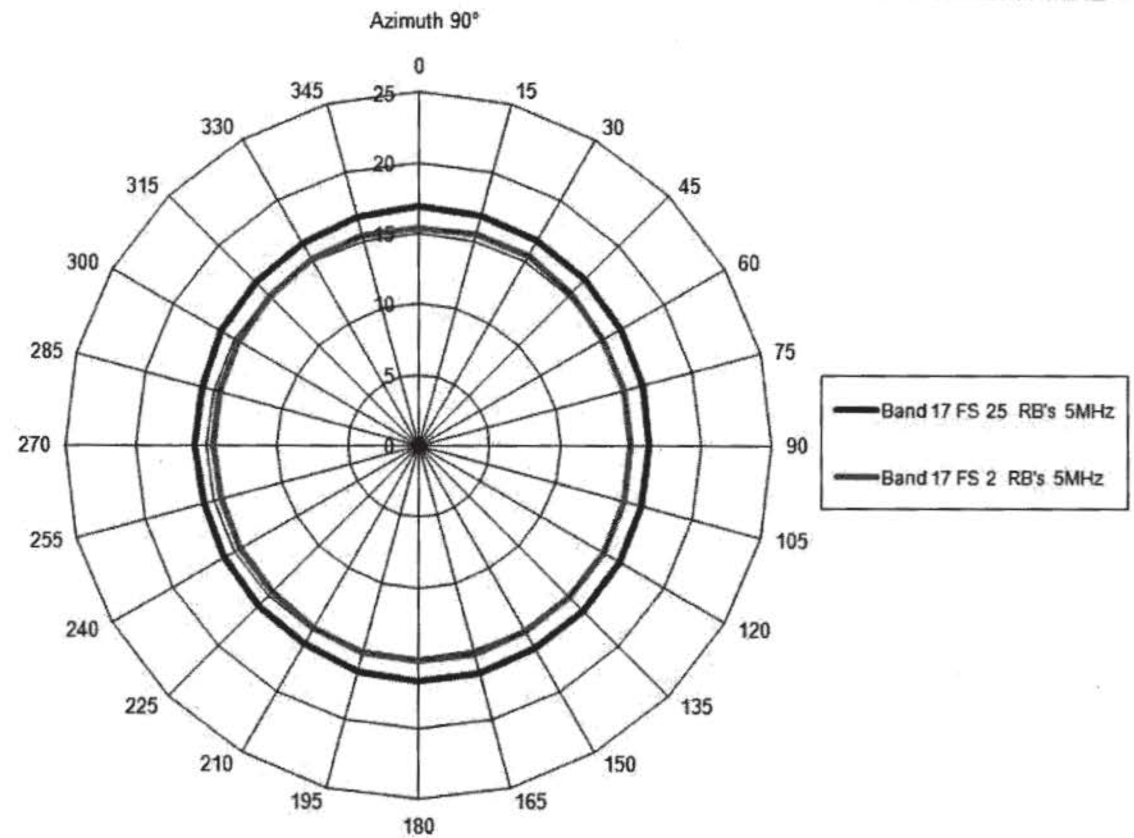


Figure 48 – Comparison of Two Bands of Galaxy Note at Azimuth 90°

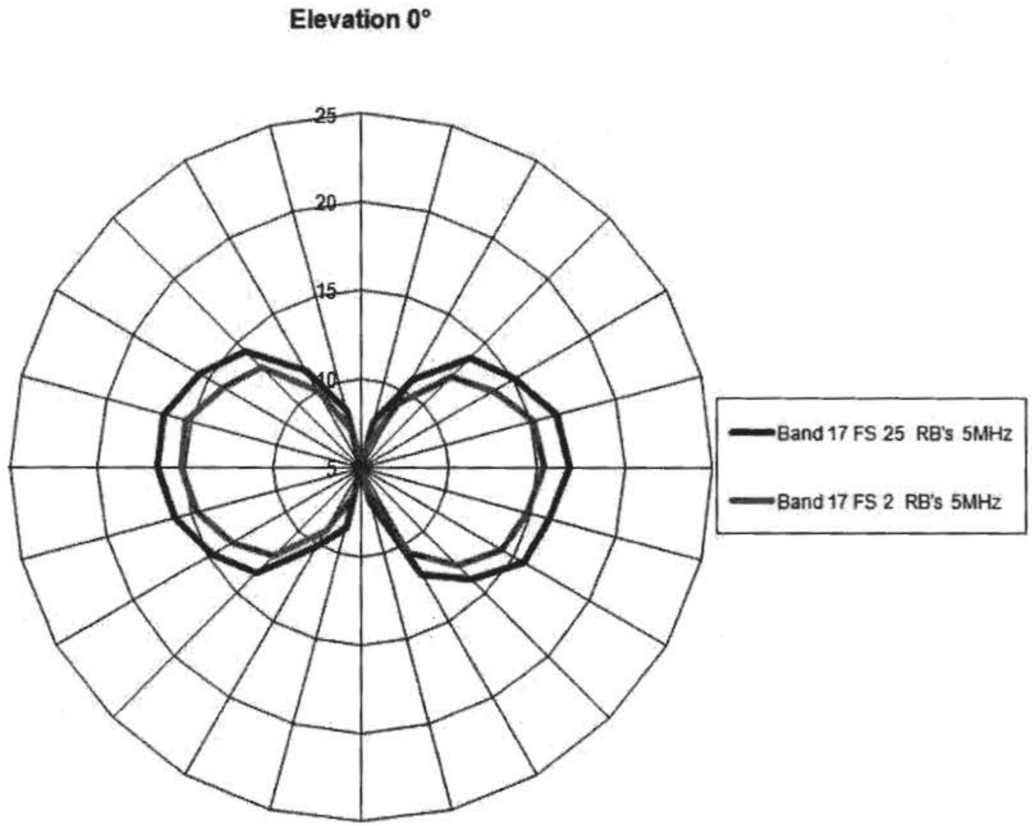


Figure 49 – Comparison of Two Bands of Galaxy Note at Elevation 0°

APPENDIX G – DTV Antenna Pattern Data

Six consumer DTV indoor antennas were tested to compare their relative performance. The antennas tested are:

- A genertic DTV indoor antenna
- Zenith VN1ANTP1
- GE Enhance 34760
- RCA Multidirectional Flat Antenna ANT1600R
- RCA Indoor Antenna ANT112R
- RCA Digital Flat Antenna ANT1050R

The graph in Figure 50 compares their relative performance for azimuth and elevation.

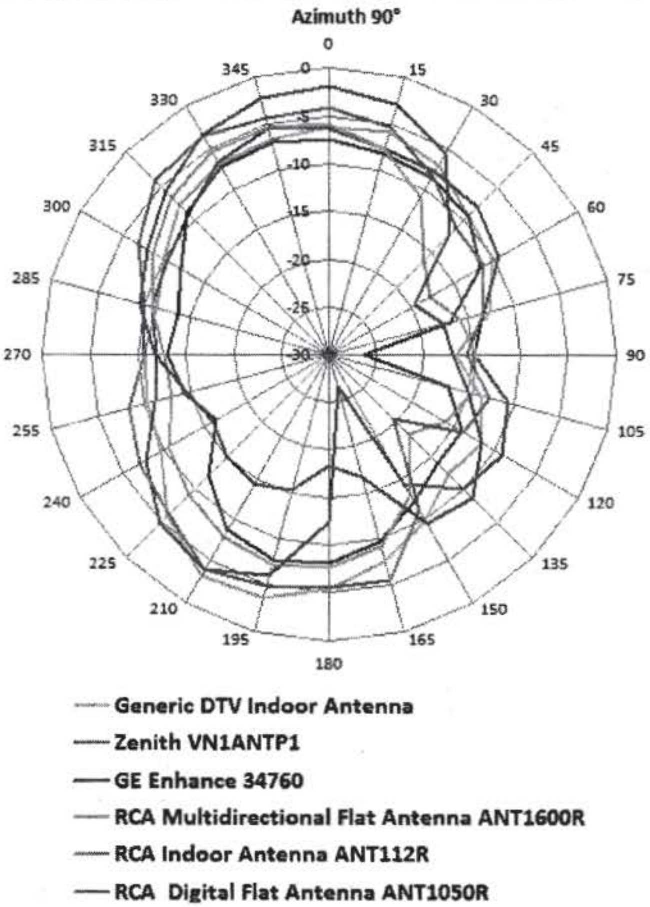
Table 59 reports the TRP for these antennas, as well as the maximum, minimum and average values for their antenna patterns.

Figure 51 through Figure 56 show the individual patterns for these indoor DTV antennas.

As can be observed there is considerable variation in the pattern, which means that the ability of at LTE UE to couple energy into the antenna will depend significantly on where it is located relative to the DTV antenna.

Table 59 – TRP for LTE UE used

Antenna	TRP	Min	Max	Average	Std Dev
 Generic DTV Indoor Antenna	-7.6 dB	-21.9 dB	-2.1 dB	-7.5 dB	-9.1 dB
 Zenith VN1ANTP1	-4.4 dB	-27.3 dB	-1.2 dB	-8.1 dB	-8.5 dB
 GE Enhance 34760	-10.4 dB	-26.3 dB	-3.7 dB	-11.5 dB	3.4 dB
 RCA Multidirectional Flat Antenna ANT1600R	-8.4 dB	-18.6 dB	-3.2 dB	-9.0 dB	3.2 dB
 RCA Indoor Antenna ANT112R	-7.5 dB	-20.5 dB	-2.5 dB	-8.2 dB	3.1 dB
 RCA Digital Flat Antenna ANT1050R	-6.2 dB	-21.5 dB	-0.7 dB	-7.1 dB	4.7 dB



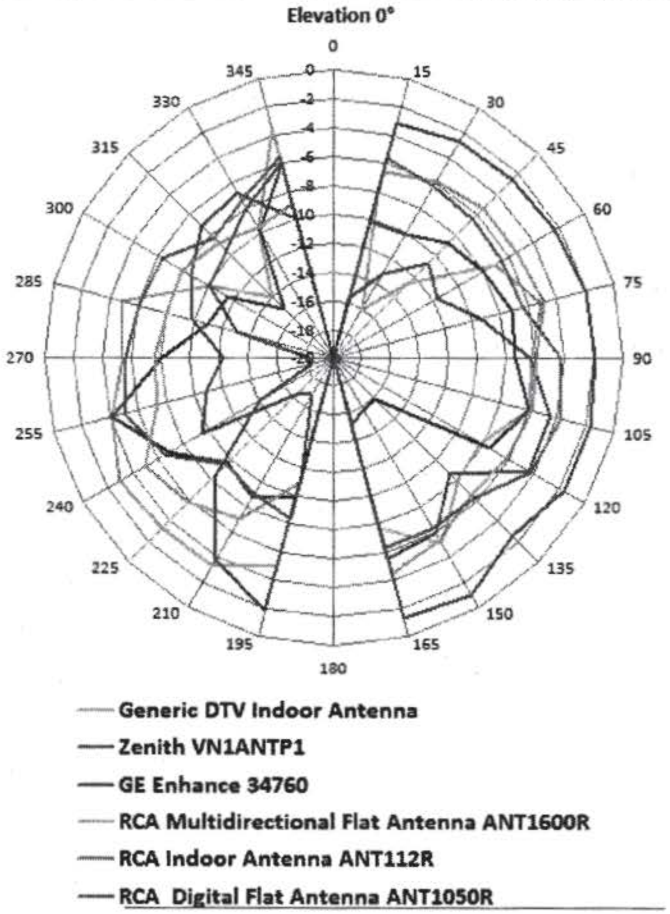
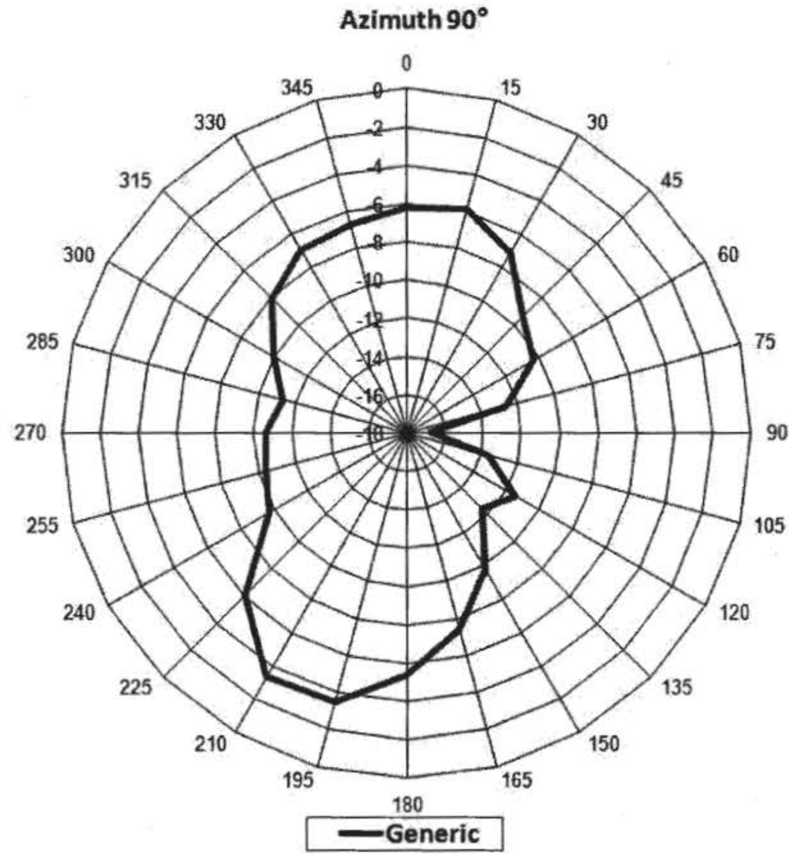


Figure 50 – Comparison of Six DTV Indoor Antennas



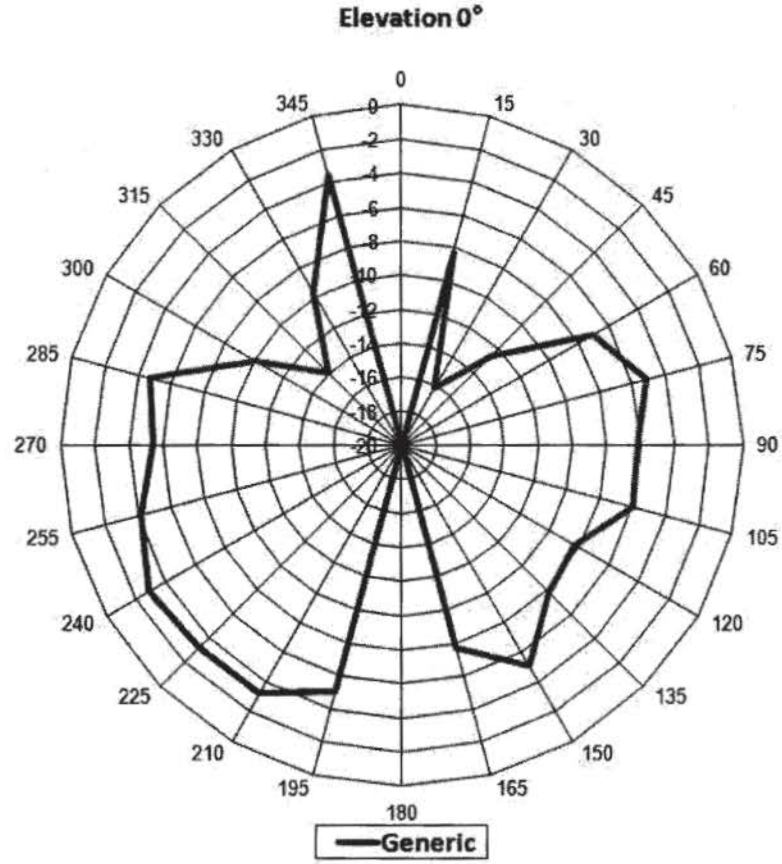
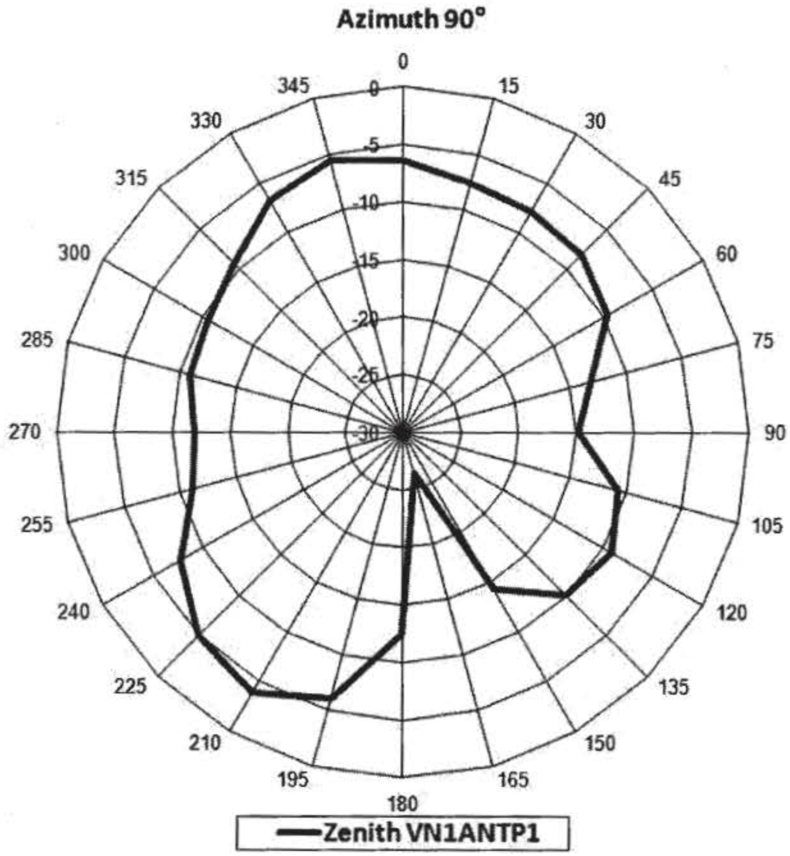


Figure 51 – Generic DTV indoor antenna



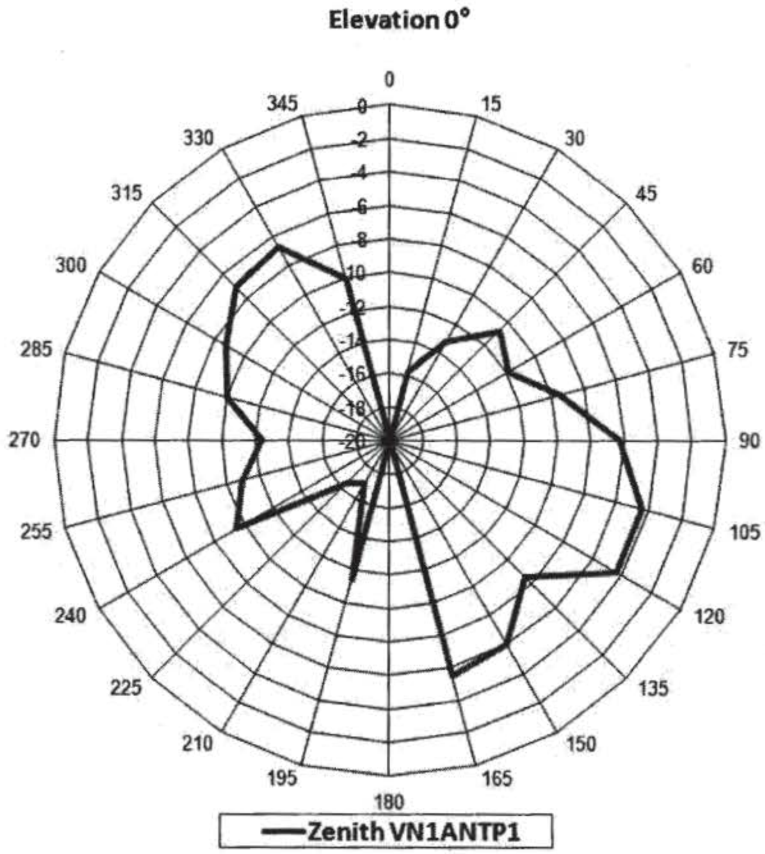


Figure 52 – Zenith VN1ANTP1

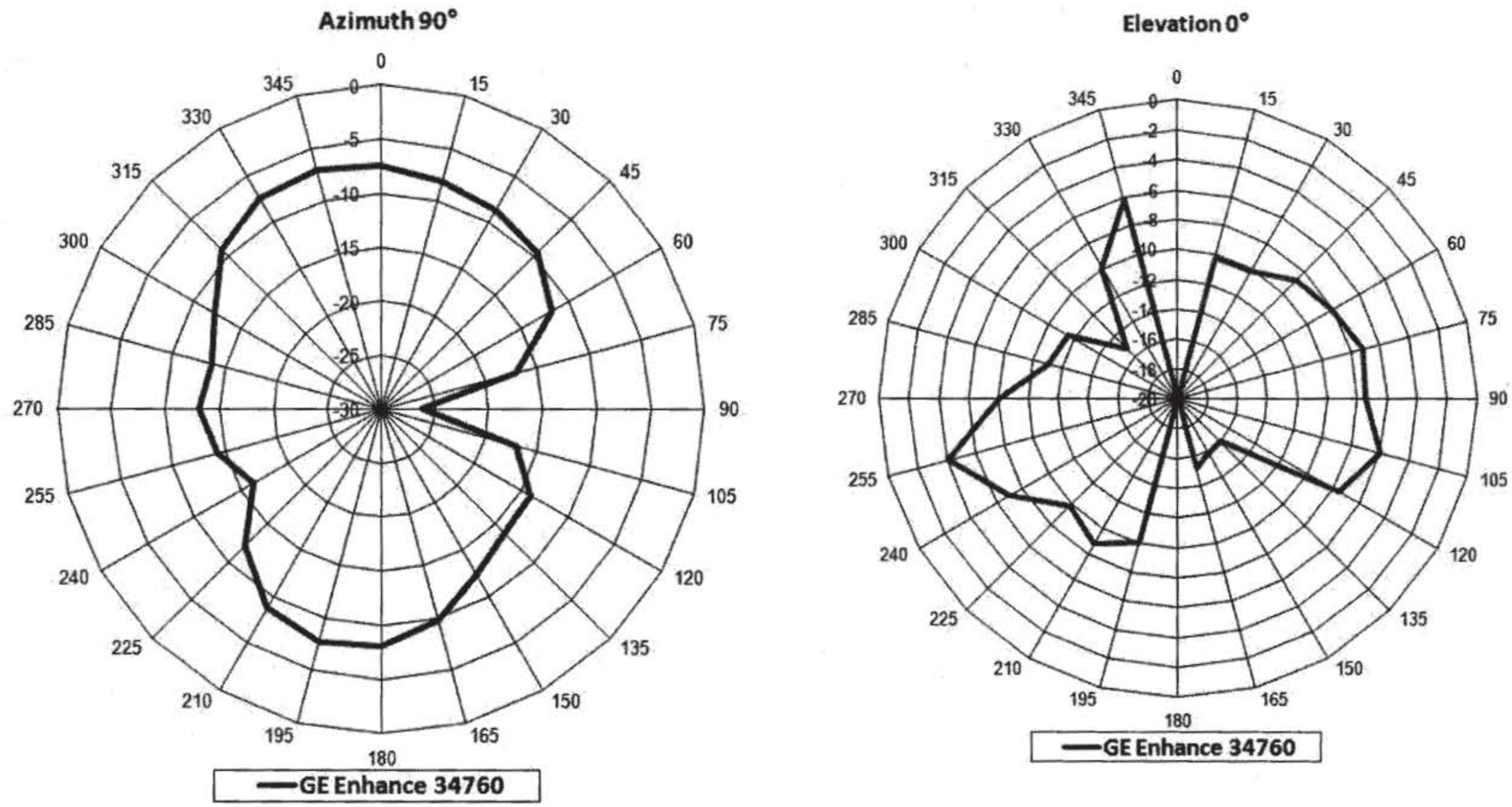
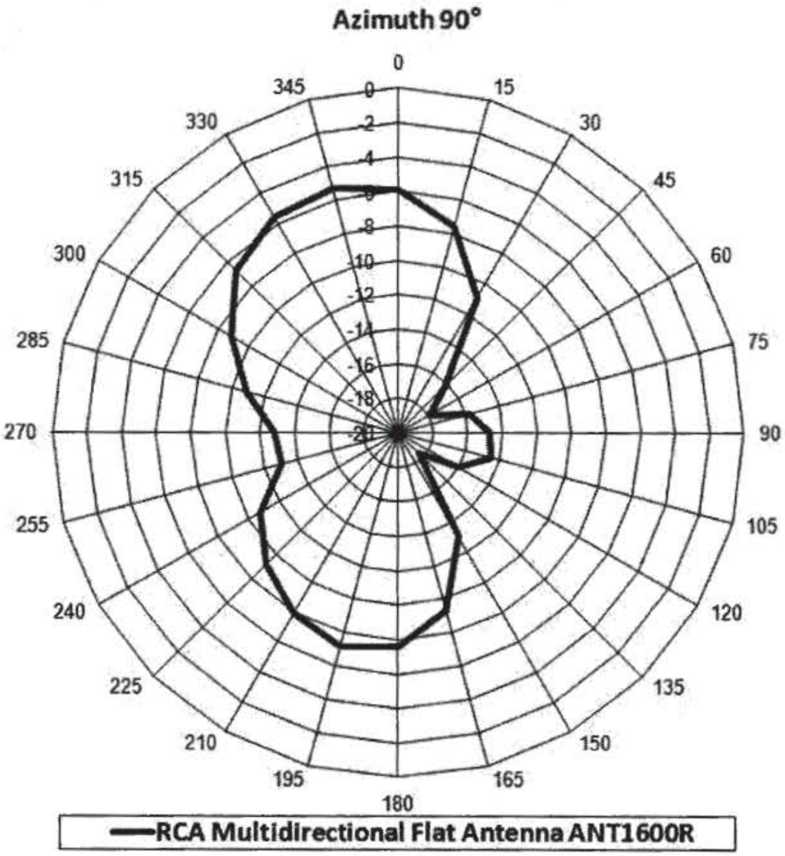


Figure 53 – GE Enhance 34760



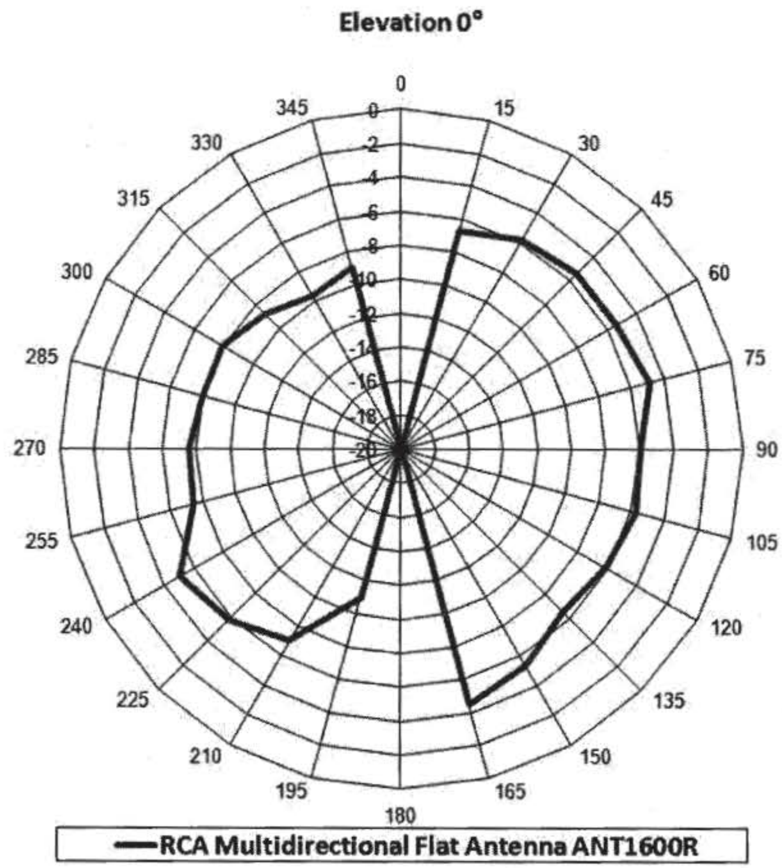
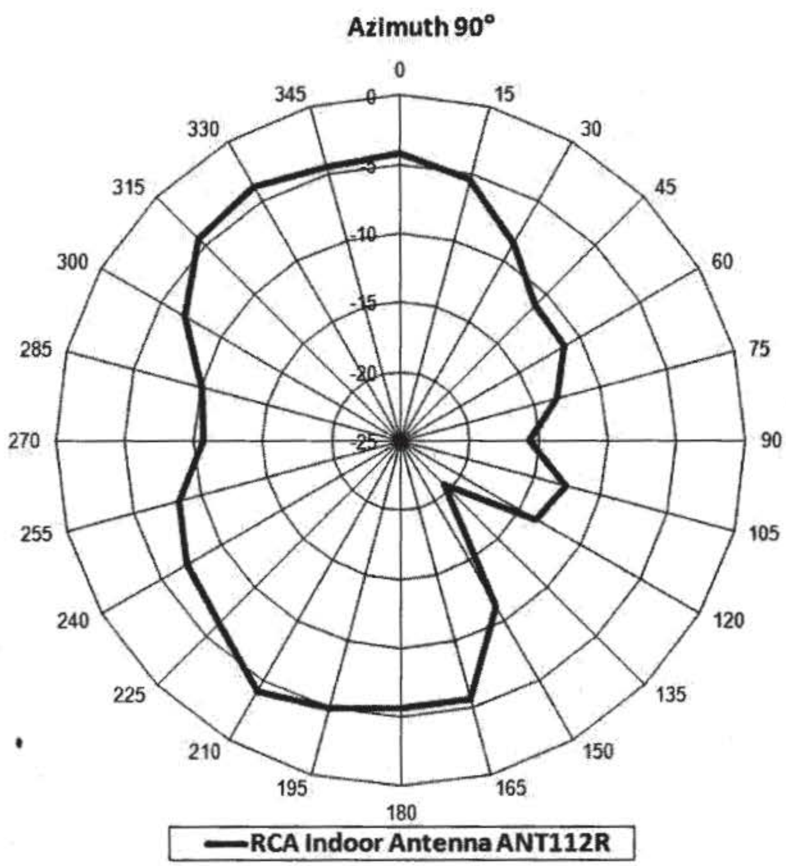


Figure 54 – RCA Multidirectional Flat Antenna ANT1600R



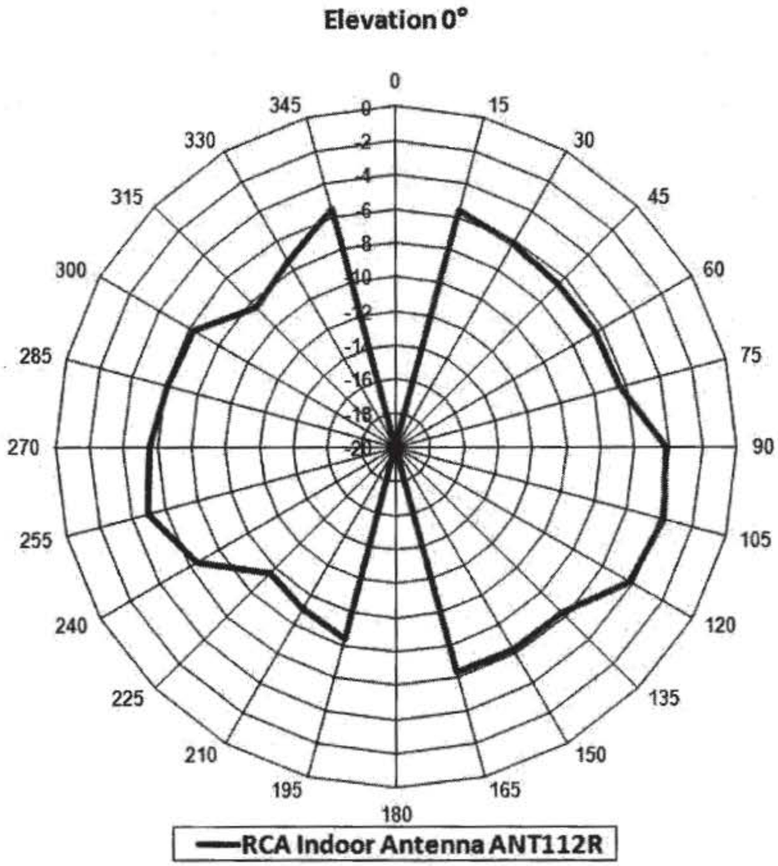


Figure 55 – RCA Indoor Antenna ANT112R

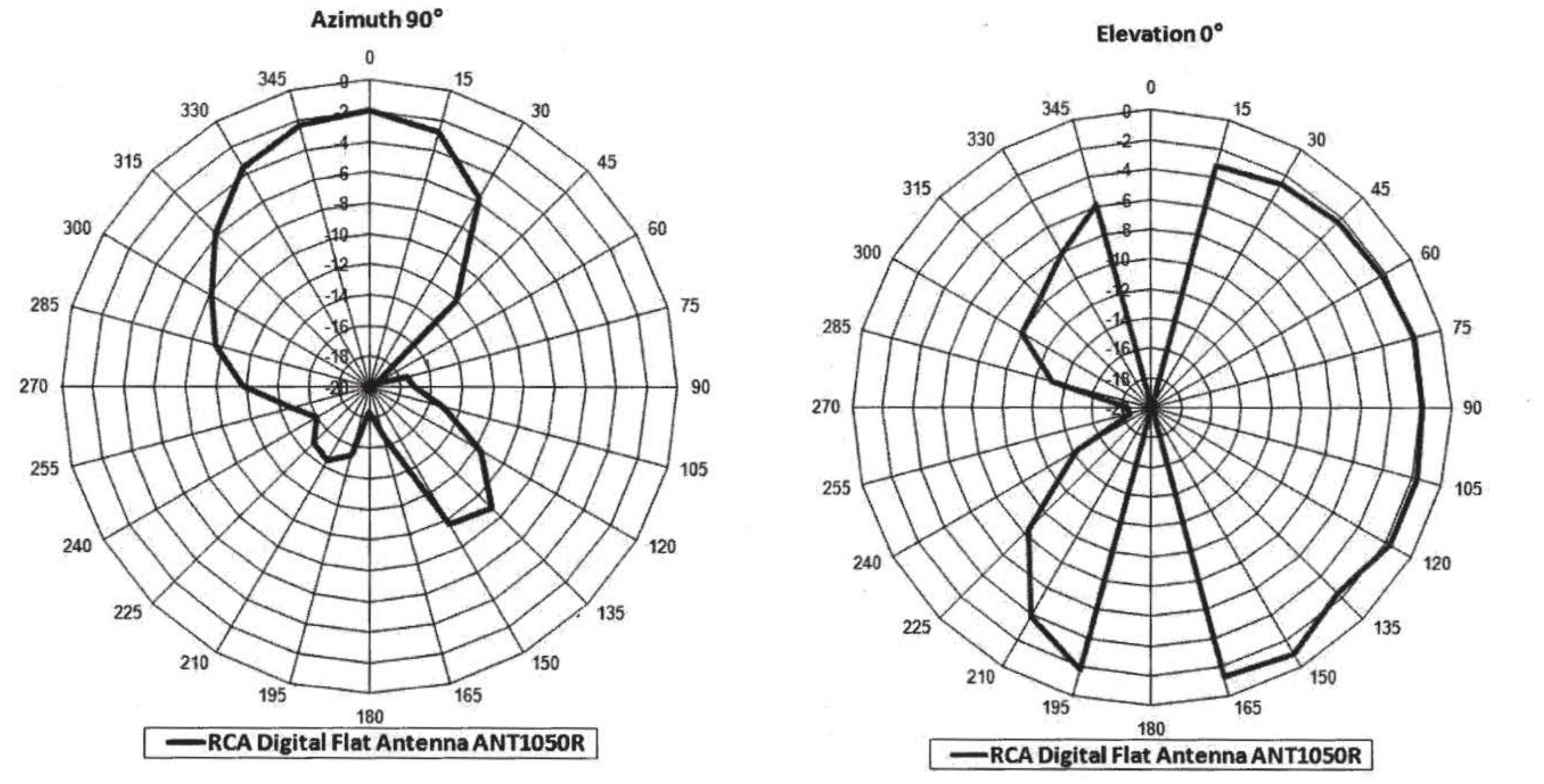


Figure 56 – RCA Digital Flat Antenna ANT1050R

APPENDIX H – BACKGROUND

H.1 FCC specifications and testing experience

"For DTV TV stations, service is defined to exist where the received signal strength exceeds the limit shown in the following table, using the F(50,90) propagation curves. These field strength values are defined in Section 73.622 and Section 73.625). "[45]

Table 60 – FCC DTV Service Area Definitions[46, 47, 48]

Channels	DTV Noise-Limited Service	Minimum Field Strength over Community of License
Channels 2 through 6	28 dBu	35 dBu
Channels 7 through 13	36 dBu	43 dBu
Channels 14 through 69	41 dBu	48 dBu

"For digital television stations, service is evaluated inside contours determined by DTV planning factors in combination with field strength curves derived for 50% of locations and 90% of the time from curves which are also found in Section 73.699 of FCC rules. The family of FCC propagation curves for predicting field strength at 50% of locations 90% of the time is found by the formula F(50, 90) = F(50, 50) - [F(50, 10) - F(50, 50)]. That is, the F(50, 90) value is lower than F(50, 50) by the same amount that F(50, 10) exceeds F(50, 50)."[49]

The defining field strengths for DTV service, contained in 47CFR73.622(e) and 47CFR73.625(a) of the FCC rules, are shown in Table 60.

"Criteria for the ratio of desired to undesired field strength are specified in Section 73.623 of FCC rules for interference involving DTV stations as desired or undesired. These criteria are summarized in (Table 61)."[50]

Table 61 - Interference Criteria for Co- and Adjacent Channels[51]

Channel Offset	D/U Ratio, dB			
	Analog into Analog	DTV into Analog	Analog into DTV	DTV into DTV
-1 (lower adjacent)	-3	-14	-48	-28
0 (co-channel)	+28	+34	+2	+15
+1 (upper adjacent)	-13	-17	-49	-26

Applying this information for the case of channel 52 to channel 51, for channel 51 the mid-frequency is 695 and the DTV Noise Limited Service calculates to 41 – 20log(615/695) = 42.1 dBu.

The FCC has conducted extensive DTV testing in its own laboratory, issuing a series of reports with findings. These reports are listed in Appendix B, as relevant bibliography for this project. A variety of insights can be gained from these reports which are relevant to this project.

45 http://transition.fcc.gov/mb/audio/bickel/curves.html
46 Service area definitions are found in 47CFR73.622(e) and 47CRF73.625(a)
47 http://transition.fcc.gov/mb/audio/bickel/curves.html
48 dBu is dB above one uV/m per 47CFR73.625(e).
49 FCC OET Bulletin 69, February 6, 2004, pgs 2-3.
50 FCC OET Bulletin 69, July 2, 1997, pg 10.
51 FCC OET Bulletin 69, February 6, 2004, Table 5A.

In its 2009 testing of DTV converter boxes a section titled, "Chapter 9 - Lessons Learned for Future DTV Receiver Testing"[52] particular offers useful information. The first area discussed was the impact of the video content on the ability to detect various failures during testing:

> **VIDEO MODE TESTING**
>
> In testing the ability of a DTV receiver to handle the 36 video modes (video formats and frame rates) specified in the ATSC standard, it is essential to use video content that includes motion, and the speed or complexity of the motion can be a factor in detection of anomalies.
>
> • Only one of the seven failures in video mode processing observed during converter box testing would have been caught by static images.
>
> • One converter box model was rejected due to image artifacts left behind during motion.
>
> • Five converter boxes were rejected for jerky motion in the video. At least one of these occurred only on images with complex motion (a myriad of fish moving in different directions) or rapid motion.[53]

The relevance of these observations to the current project needs to be explored. The DTV test signal will be selected to maximize the ability to detect signal interference.

> **AGC MEMORY / HYSTERESIS**
>
> The automatic gain control (AGC) state of a DTV receiver can have a profound effect on interference thresholds because many interference mechanisms involve nonlinearities in the tuner. A high gain prior to a tuner stage that exhibits a nonlinearity causes higher signal levels at the point of the nonlinearity — and, consequently, higher levels of the spectral products created by that nonlinearity relative to the level of the desired signal.
>
> Prior to the converter box testing, we had assumed that the AGC state of a DTV receiver was a function only of its current input. It was found, however, that some converter boxes exhibited a hysteresis or memory effect in the AGC function, such that, if a given undesired signal level is approached from above, the results are different from those obtained by approaching the same level from below. Exposures to high undesired signal levels were "remembered" by the AGC loop and played a part in setting the AGC state. A channel change was found to reset this "memory".
>
> To ensure consistency in the test results, additional steps were added to the process of finding the TOV during interference tests. In particular, when an interference level was adjusted close to the TOV level, the tuner channel was changed from the desired channel to the undesired channel, then back again. The search for TOV then continued. If the undesired level changed by one dB or more in this search, the channel change step was repeated, the search for TOV continued. This process was repeated as necessary to ensure that the channel change occurred with the undesired signal level less than 1 dB from its final value.

The issue of ACG hysteresis is significant and will be reflected in the specific steps of the test procedure. To clarify the nomenclature the terms TOV-A and TOV-D will be used in the document. TOV-A being the threshold of visibility with an ascending signal, meaning the transition from no visible picture to visibility. TOV-D would then be the threshold of visibility found with a descending signal, meaning the threshold found when transitioning from a visible picture to no visible picture. In both cases the threshold of visibility will be the last viewable picture.

> **TOV VERSUS SIGNAL ACQUISITION LEVELS**
>
> RF performance measurements for DTV receivers are generally presented in terms of desired signal level, undesired (interference) signal level, echo level, or noise level at the threshold of visibility (TOV) of TV picture degradation. However, some DTV receivers require better signal conditions to initially acquire a DTV signal than they require to maintain a visually flawless picture once the signal has been acquired. If one gradually decreases the desired signal level until TOV is reached, the resulting signal level may not be adequate for the receiver to acquire the

[52] FCC OET Bulletin 9-TR103, DTV Converter Box Test Program--Results and Lessons Learned, October 9, 2009

[53] Ibid, pg 9-1

signal when the receiver is initially turned on or the channel is initially selected. The same is true of gradually increasing an impairment (interference, noise, or multipath) until TOV is found.

A TOV measurement made using the methodology above would provide a false indication of performance of the DTV receiver because it would correspond to a signal condition that is inadequate for initial reception. In order to avoid creation of misleading results, after TOV was identified by gradually decreasing the desired signal level or gradually increasing an impairment or interference level, a channel change was executed on the converter box, followed by returning to the original channel. Most converter boxes reacquired the signal quickly; however, if a converter box was unable to reacquire the signal within 20 seconds after returning to the test channel, the desired signal level was increased or the impairment was decreased until the converter box was capable of signal acquisition after a channel change. In such cases, the reacquisition signal level was reported as the TOV.

This issue is also significant and will be addressed in the specific steps of the test procedure.

UNINTENDED PHASE NOISE OF SIGNAL SOURCES IN RF PERFORMANCE TESTS

The FCC Laboratory found—in preparatory work for the converter box test program, as well as in earlier test programs—that degraded quality of DTV signals used for testing can impact test results on DTV receivers. Work that we performed in preparation for the converter box program identified unintended phase noise in both internal and external RF upconverters associated with DTV signal generation equipment as the likely cause of this degradation. Degraded test results were observed in sensitivity and taboo test results as a function of the DTV signal generator selected to produce the desired signal, as well as in field-ensemble tests, as a function of the upconverter used with the RF player.

Observed Impact of Signal Source Quality on DTV Receiver Test Results

The FCC has observed degraded DTV receiver test results caused by test equipment on four occasions.

(1) In tests reported in 2007 on consumer DTV receivers that were on the market in 2005 and 2006, sensitivity of the receivers was found to be poorer by an average of 0.9 dB when the desired signal was supplied by an early-generation Sencore ATSC997 ATSC signal generator than when it was supplied by a Rohde and Schwarz SFU. Modulation error ratio (MER) measurements on the ATSC997 source were sufficiently high as to explain no more than 0.14 dB of the discrepancy.[54]

(2) In the same test program, measured taboo-channel rejection performance of eight DTV receivers was 1.0 dB poorer on average when the desired signal was supplied by the ATSC997 as compared to the SFU that was mentioned above in item (1).[55] (For tests in items (1) and (2), the ATSC997's internal RF upconverter was used. The measurements were performed less than 12 months after a 2006 calibration of the ATSC997. The instrument was purchased in October 2001 and may differ in performance from more recent models.)

(3) In tests reported in 2005, the average number of field ensembles (out of 47) that were demodulated with no visible errors by a tested DTV receiver increased from 10 to 31 when Sencore replaced the RF upconverter card in the Sencore RFP-910 RF Player that was used in the tests.[56] The average number of field ensembles (out of 50) that were successfully demodulated with two or fewer visible errors by six DTV receivers increased from 14 to 40 with the change in upconverter cards.[57]

[54] <Interference Rejection 2007>, p.5-5 and 5-6.

[55] <Interference Rejection 2007>, p.7-3 through 7-5.

[56] Martin, Stephen, "Tests of ATSC 8-VSB Reception Performance of Consumer Digital Television Receivers Available in 2005", Federal Communications Commission Report FCC/OET TR 05-1017, November 2, 2005, p. A-5.

[57] This previously unpublished result is from the same set of tests performed in 2005. The actual increase was from 11 to 37 for the number of successes out of the 47 ensembles with video content. As discussed elsewhere in this report, the three ensembles that lack video content were judged to be easily demodulated, so three was added to each result to be consistent with results reported elsewhere in this document.

(4) An early-generation Wavetech WS-2100 RF player was purchased for field-ensemble tests in the converter box program. An initial performance evaluation of the player was conducted by using a DTV receiver that was known to exhibit visible errors on specific field ensembles when played on an RF player with degraded signal quality. Visible errors were observed when upconversion to RF was performed by the Wavetech's internal RF upconverter (an upconverter that was replaced with another brand in subsequent production of the WS-2100) or by an external Blonder Tongue DHDC-UH upconverter installed in an MIRC-4D rack mount. On the other hand, no such errors were observed when the RF player was used with an external Drake DUC860 upconverter in DRMM4 rack mount.[58]

The RF player results clearly indicated that RF upconverter performance can influence field-ensemble test results. Subsequent tests, described below, suggested that the observed degradation in DTV receiver sensitivity and taboo measurements made with the ATSC997 signal source was also related to upconverter performance and that phase noise was the likely cause of the degradation.

The discussion of TOV in the technical report of the FCC Advisory Committee on Advanced Television Service, ACATS, provides useful information:

5.2. TRANSMISSION ROBUSTNESS

This section identifies the various tests of transmission performance. For each test, the purpose and importance of the test and the test methodology is summarized. A brief statement of the results is given also for each test, with emphasis on comparison of performance of this Grand Alliance system with the previous proponent systems.

5.2.1. Random RF Noise Performance

Random noise was added at RF to the desired digital signal. As expected for the Grand Alliance system's modulation and error correction, random RF noise has no effect on the recovered video and audio data until the level of noise is raised to a point very close to a "threshold" value. The value of carrier-to-noise ratio (C/N) where the effects of noise begin to be visible is called the Threshold of Visibility (TOV).

For the Grand Alliance system, the C/N at TOV was 15.19 dB.

As expected and designed into the system, the threshold is very sharp. Visible image impairments change from just barely visible to destructive of the picture within ~ 1 dB of worsening of the C/N.

A similar measure can be made on the recovered audio data (Threshold of Audibility). For the Grand Alliance system, the C/N at TOA was 14.92 dB.

As expected, the video and audio fail approximately together, with audio measuring as slightly more robust against RF noise. Audio does not fail before video.[59]

In this test plan TOV was assessed based on the video rather than the audio signal. As the ACATS report observed, the video and audio signals fail approximately together with the video being slightly more fragile. It is also noted that the threshold is relatively sharp, which benefits its accurate assessment.

An issue which must be addressed is the amount of time the video should be viewed in order to be confident that the TOV has been accurately determined. For E911 compliance the FCC requires that sufficient observations be made to have a 90% confidence level of compliance:

A sufficient number of observations should be included to establish compliance with the FCC accuracy requirements with a statistical confidence of at least 90 percent. See Appendix A for a statistical approach for demonstrating compliance for empirical testing.[60]

---

58 As with many types of DTV signal sources, the Wavetech RF player has an IF output that can be fed to either an internal RF upconverter or an external upconverter to convert the IF signal (centered at 44 MHz) to an RF signal on a specified broadcast television channel.

59 Technical Report of the FCC Advisory Committee on Advanced Television Service, ACATS, October 31, 2010.

60 FCC OET Bulletin 71, pg 6.

FCC OET Bulletin 71 Appendix A and TIA 916 Appendix C provide helpful discussion and guidance on calculating the number of observations necessary for a given confidence level. ATSC A/54a defines TOV as the level at which there are 2.5 data segment errors per second. Experience with evaluating the TOV threshold has led to the conclusion that the number of observations per second is close to the frame rate. Noticing an error block is generally quite easy even if it is just for a brief flash. The change using a 0.5 dB step size increment at the TOV threshold proved to be clearly observable. A 10 to 30 seconds observation time proved more than adequate for determination of TOV.

H.2 DTV Receivers

Performance of DTV receivers is expected to have similarities based on the chip set used. Receivers using the same chip set are expected to perform similarly. Therefore sampling DTV receivers that use the latest generation chip is one important criterion for obtaining a representative sample of the population.

Six generations of 8-VSB chip sets have been introduced to the market. The following is a summary of 8-VSB chip sets performance for consumer-grade DTV receivers:

1. First generation chip sets, 1998. Could only compensate for reflections ("ghosts") between -3/+20 uSec, and at least 3 dB weaker than the direct signal.
2. Second generation chip sets, 1999. The ghost compensation range was unchanged, but the chip set went from 3 to 2 integrated circuits, with reduced footprint and power requirements.
3. Third generation chip sets, 2000. The ghost compensation range was increased to -3/+44 uSec, and slightly stronger ghosts, of no more than 2.5 dB weaker than the direct signal, could be accommodated. This generation still used two ICs.
4. Fourth generation chip sets, 2002. The ghost compensation range was increased to -10/+44 uSec, and even stronger ghosts, of no more than 1.5 dB weaker than the direct signal, could be accommodated. This generation still used two ICs.
5. Fifth generation chip sets, 2005. Ghost compensation range of ±50 uSec, and ability to accommodate 0 dB (same amplitude as direct signal) ghosts. This generation used only one IC, for both 8-VSB and QAM.
6. Sixth generation chip sets, 2007. Ghost compensation range of ±73 uSec, and ability to accommodate 0 dB reflections; ATSC A/74 "compliant." This generation used only one IC, both 8-VSB and QAM decoding supported.

It is believed that first through third generation chip sets were generally only used by a relatively small group of "early adopters." Fifth and sixth generation chip sets allowed for significantly more reliable DTV reception and dominate both current DTV receiver's on the market and in the installed base. Therefore, the sample of devices selected with focus on DTV receiver's that use these generation chip sets.

H.3 ATSC Standards

The ATSC standards identify 18 different video encoding and compression formats, which combined with the M/H signal results in 36 different encoding and compression formats.

spec	Horizontal pixels	Vertical pixels	Aspect ratio	Monitor interface	Format name	Frames per sec	Fields per sec	Transmitted interlaced
ATSC	1920	1080	16:9	1080i	1080 60i	30	60	yes
					1080 30p	30	30	no
					1080 24p	24	24	no
	1280	720	16:9	720p	720 60p	60	60	no
					720 30p	30	30	no
					720 24p	24	24	no
	704	480	16:9	480p	480 60p	60	60	no
				480i	480 60i	30	60	yes
					480 30p	30	30	no
					480 24p	24	24	no
	704	480	4:3	480p	480 60p	60	60	no
				480i	480 60i	30	60	yes
					480 30p	30	30	no
					480 24p	24	24	no
	640	480	4:3	480p	480 60p	60	60	no
				480i	480 60i	30	60	yes
					480 30p	30	30	no
					480 24p	24	24	no
NTSC	≈640	483	4:3	Note 1	NTSC	30	60	yes

Figure 57 – ATSC signal formats[61]

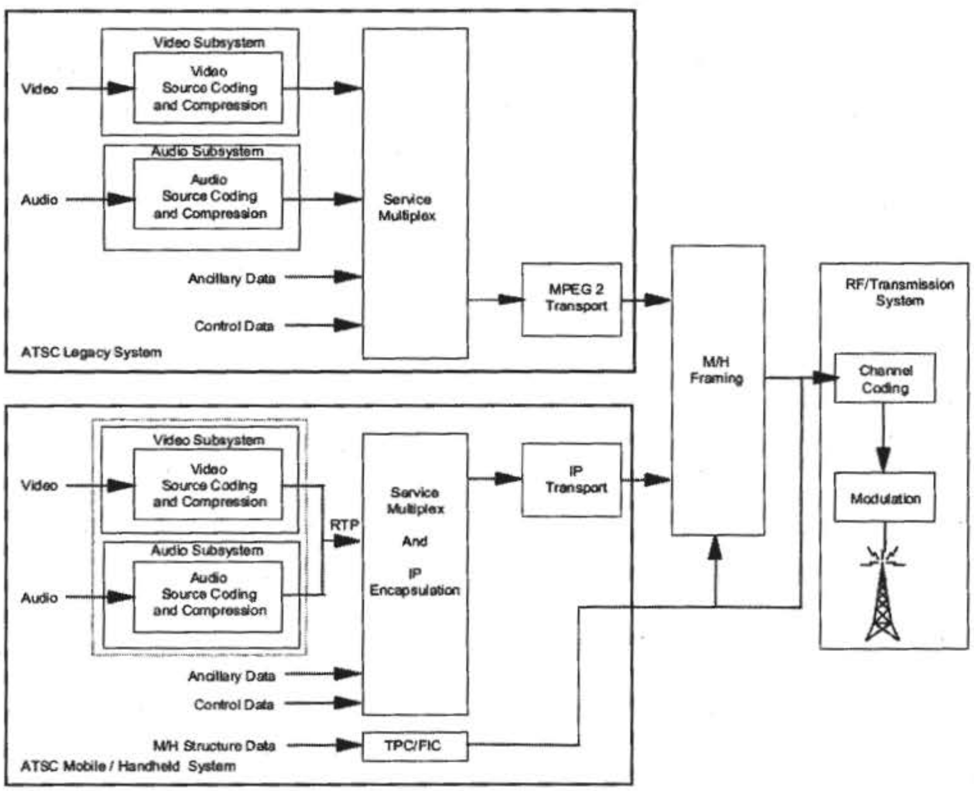


Figure 58 - ATSC broadcast system with TS Main and M/H services (Figure 4-1 from ATSC A/153-7)

61 Source: http://www.hdtvprimer.com/ISSUES/what_is_ATSC.html